Pacific Area Distribution of Fresh-Water and Marine Cercarial Dermatitis[1]

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CERCARIAL DERMATITIS, a form of "swimmer's itch," is a skin infection caused by the penetration of schistosome cercariae. The disease is also known as schistosome dermatitis. The clinical symptoms start with an itching sensation, which is followed by the development of a rash or petechiae, and in many hypersensitive persons papular eruptions appear together with intensive itching and edema. It is a self-limiting ailment if no further infection is contracted. It is neither a communicable disease nor a fatal one, but the discomfort and the pathology of the infection contribute to its importance in the field of public health and veterinary medicine.

The disease is of geographical interest because it is a "Disease of the Place," as explained by Jarcho and Van Burkalow (1952). Normally the adults of the dermatitis-producing schistosomes are blood parasites of birds, or, in some instances, of mammals. The life cycle begins with the hatching of the eggs which are present in the droppings of infected animals. Suitable species of snails become infected upon contact with the miracidia hatched from the eggs, the snails serving as the intermediate host. After a proper incubation period in the snail, the infectious schistosome cercariae are issued into the surrounding water. Upon exposure to these cercariae, the bird or mammalian definitive hosts are infected and the parasites mature in the vascular system of the hosts. The life cycle is completed when the adult worms produce eggs. Humans contracting the cercarial dermatitis are only the result of accidental intrusion into the life cycle of these interesting parasites.

Therefore in any geographical area, the conditions responsible for the occurrence of cercarial dermatitis are: (1) the presence of birds infected with dermatitis-producing schistosomes, (2) the presence of the snail intermediate hosts with habits conducive to the acquisition of the disease, (3) ecological conditions favorable for the survival of both the hosts and the parasites, and (4) the presence of human beings engaged in an activity which exposes them to the infection. In many parts of the world these four basic factors are present, and, as a result, the distribution of cercarial dermatitis is worldwide (Cort, 1950; Kuntz, 1955).

In the Pacific area, the disease occurs at various locations on the west coast of the North American continent extending north to Alaska. It has been reported from Japan, the Federation of Malaya, Australia, and as far south as New Zealand. The Hawaiian Islands chain is not entirely free from the presence of this disease. The following report is an attempt to summarize from the literature[3] the important facts concerning the vectors and reservoir hosts of cercarial dermatitis and to emphasize the distribution and transmission of both fresh-water and marine schistosomes in various parts of the Pacific.

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A. FRESH-WATER CERCARIAL DERMATITIS

1. *United States and Canadian Pacific Coasts*

The etiology of swimmer's itch was first elucidated by Cort in Michigan, U. S. A., in 1928. Since that time, it has been recognized that "nonhuman" species of schistosomes are responsible for many cases of swimmer's itch. In the United States and Canada, Jarcho and Van Burkalow (1952) indicated recently in their report that "the states most strongly affected are Michigan, Wisconsin, and Minnesota. A few clinical cases (cercariae not identified) have been reported from the neighboring states of Indiana, Illinois, Iowa, Nebraska, and North and South Dakota. In Canada the major areas are in Ontario, east of Georgian Bay; in Manitoba, in and near Lake Winnipeg; in Saskatchewan; and in Alberta." Other areas mentioned in the text include: British Columbia, Washington, Oregon, Quebec, New York, Maine, Nevada, Oklahoma, Alabama, Tennessee, and Florida. The disease is common in lakes and swamps along the flyways of migratory water fowls.

Recent data, together with previous reports relative to the following Pacific states, are given as follows:

a. *Washington.* Miller (1925, 1927) was first to describe the presence of schistosome cercariae in the northwestern United States. *Cercaria elvae* from *Lymnaea stagnalis* Linn. and *Cercaria tuckerensis* from *Planorbis* spp. were obtained from Trout Lake, San Juan Sound, Washington. Swimmer's itch in the Seattle area was shown by Hunter, Shillam, Trott, and Howell (1949) to be caused by two agents: (1) the cercariae of *Trichobilharzia ocellata* (La Valette) (=*C. elvae*) from *Stagnicola palustris nutaliana*, and (2) *Cercaria physellae* of *T. physellae* (Talbot) from *Physella propinqua* (Tryon). The former species of snail was found associated with reeds and other aquatic vegetation growing in the gravel and mud bottom of the lake. It was thought that the cercariae from infected snails were carried to shore by currents created by the wind blowing towards the beaches. A similar situation was known to have existed in Douglas Lake, Michigan (Cort, 1936).

The definitive hosts for these parasites in Washington have not been described, but, according to McMullen and Beaver (1945), *C. physellae*, whose definitive host was reported to be the blue-winged teal, *Querquedula discors* (Linn.), was also infective to pigeons, mallards, and canaries; however, a Caspian tern, chickens, domestic ducklings, and gulls could not be infected. The blue-winged teal is also the definitive host of *T. ocellata* (=*T. Kossarewi*), but McMullen and Beaver showed that canaries, domestic ducklings, mallards, and pigeons could be the experimental hosts. (Chicks and a tern were resistant.) Recently Farr and Blankemeyer (1956) described a new species of schistosome, *Trichobilharzia brantae*, whose definitive host was a Canada goose (*Branta canadensis* L.) from the Turnbull National Wildlife Refuge, Washington.

Macy (1952) demonstrated that *C. elvae* from *Lymnaea stagnalis* was the causative agent for dermatitis cases at Cascade Lake, Orcas Island. Macy (1955) further reported that dermatitis cases were found at a lake south of Tacoma, Washington, and from Lake Chelan and Goose Lake, Okanogan County, in eastern Washington. In spite of the fact that a large number of lakes in the state of Washington might have harbored schistosome-infected snails, Dr. W. R. Giedt, chief of Division of Epidemiology and Laboratories of the Department of Health, received only ten reports of cases in 1955 and ten during 1956 (personal communication, 1957). Since swimmer's itch is not a reportable disease, these statistics are probably incomplete. However, the preventive measures advocated by the health officers of Washington with regard to control and avoidance of the infection must have been successful, as is indicated by the low incidence of infections.

b. *Oregon.* Macy (1955) investigated schistosome dermatitis cases in the Blue Lake area near Troutdale, Oregon. The causative agent, *C. oregonensis* from *Physa ampularia*, was a schistosome species originally described by Macfarlane and Macy (1946). It is interesting to note that these infected snails occurred most abundantly on dead or decaying vegetation in lakes, ponds, and marshes. They laid their eggs in late summer and the next generation of snails matured enough to lay their eggs during the early spring. Snails infected during late summer could carry the schistosome through the winter; thus in the following spring and summer, infected snails of both the old and new generations might produce cercariae for a longer time and therefore possibly might cause a higher level of infection in humans.

c. *California.* Simmons, Martin, and Wagner (1951) reported that the first case of freshwater cercarial dermatitis in California was derived from an artificial lake at Alendra Park in Los Angeles County. Schistosome cercariae of three different types were obtained from *Physa osculans* (Haldeman) found in this lake. The taxonomic consideration of these cercariae is currently delayed because of the efficient control of the intermediate hosts by health officers (personal communication from Dr. W. E. Martin, 1957). Walker (1954) investigated a suspected outbreak of schistosome dermatitis at Twain Harte Lake, Tuolumne County, and found bifurcated cercariae coming from a mixture of *Physella* and *Lymnaea* snails. Taxonomic determinations of the schistosomes involved in these dermatitis cases are yet to be announced. Keh and Grodhaus (1957) reported swimmer's itch at a duck club in Yuba County. Cercariae of the "*ocellata*" group were obtained from *Physa* snails and later proven by experimental infection to belong to the *Trichobilharzia* group of bird schistosomes. As yet, there is no report of schistosome infected snails or cases of cercarial dermatitis in northern California.

d. *Canada.* As indicated previously, migratory water fowls such as the blue-winged teals are known to be the definitive hosts of dermatitis-producing schistosomes. Because of the many glaciated lakes and swamps which act as bird refuges, cercarial dermatitis in Canada is known to occur in many areas. Along the Pacific coast of Canada, only two species of dermatitis-producing schistosome cercariae have been reported. These cercariae were believed to be the agents responsible for a severe outbreak in 1950 at Cultus Lake, B. C. Edwards and Jansch (1955) described these two species as *Cercaria adamsi* and *C. columbiensis*, which have *Physa coniformis* Tryon as the intermediate host. The adult forms of *C. adamsi* are now designated as *Trichobilharzia adamsi* Edwards and Jansch, 1955. The definitive hosts for *C. adamsi* were believed to be wild water fowl because domestic ducks could be infected experimentally. The authors suggested that the close resemblance of *C. columbiensis* to the cercariae of *Gigantobilharzia huronensis* Najim would indicate that the pas-

seriform birds might be the natural definitive hosts for *C. columbiensis*. Goldfinches and cardinals are known to be the hosts for *G. huronensis*.

2. *Alaska*

Students interested in cercarial dermatitis have long suspected that the disease may be present in Alaska because this region is the home of many migratory water fowls (Gabrielson, 1952). Harkema (1953, 1954, 1955, 1957) reported in a series of papers that swimmer's itch occurred in the Fairbanks and Yukon Flat areas in the Alaskan interior. He made a study of the life history of one of the two schistosome cercariae obtained from infected snails in this area. A total of 80 bodies of water was investigated during the summers of 1952 and 1953, and 20 of these 80 harbored infected snails of the species *Lymnaea palustris*, *L. stagnalis*, and *L. auricularia*. The incidence of the infection in snails seemed to vary according to location and time of the year. Additional localities having infected snails were reported in 1957.

There were no extensive human infections derived from avian schistosomes in Alaska. Some cercarial dermatitis cases were observed in the Fairbanks area in the vicinity of Fort Yukon. Harkema (1957) used cercariae from the naturally infected *Lymnaea stagnalis* for experimental infections of ducklings, and the adult worm was identified as *Trichobilharzia alaskensis* Harkema, McKeever, and Becker. The other type of schistosome cercaria remains unidentified. However, two naturally infected baldpate ducks harbored adult schistosomes belonging to the genus *Trichobilharzia*. So far there has not been an extensive study of the bird definitive hosts for schistosomes in Alaska.

Gabrielson (1952), in discussing Alaskan waterfowls and their management, stated that "Alaska has breeding populations of the Whistling Swan, Emperor Goose, White-cheeked Goose, Lesser Canada Goose, Cackling Goose, White-fronted Goose, and Black Brant. It also provides suitable nesting habitats for impressive numbers of Pintails, Mallards, Green-winged Teals, Baldpates, and Shovelers, among shallow water ducks." He thinks that the Yukon delta is not only the most important breeding area in Alaska, but one of the great waterfowl production units of the continent. The green-winged teals, pintails, and baldpates, which have an extensive continental breeding range, are less affected by man-made changes in Alaskan topography than are the other species of waterfowls. Therefore in the future, the baldpates, green-winged teals, and pintails are more likely to be implicated as reservoir hosts for the distribution of avian schistosomes.

3. *Mexico and El Salvador*

Possible fresh-water cercarial dermatitis from Lake Texcoco near Mexico City was reported by Cort (1950), but so far is unconfirmed. As far as this reviewer is aware, the only cases of swimmer's itch south of Mexico along the Pacific were those contracted from Lake Coatepeque, El Salvador, and reported by Reyes in 1944. According to Cort's account of the investigation by Reyes, the exact etiological agent was not identified. Jarcho and Van Burkalow (1952) reported that a blue-winged teal captured in this area had migrated from Douglas Lake, Michigan—the area where Professor W. W. Cort first found the cause of swimmer's itch. These blue-winged teals, according to these authors, migrate along the Mississippi River and the Atlantic coast flyways. The wintering grounds involved a large geographical area ranging from southern Florida, Texas, California, through Central America to parts of the northern South American continent, while the breeding grounds extend from the Great Lakes region westward to the Rockies and as far north as northwestern Canada.

Gabrielson (1952) showed that certain species of migratory fowls did migrate as far south as Mexico and that they could be recovered in British Columbia and the states of

Washington, Oregon, and California. Thus it is no surprise that swimmer's itch along the Pacific coast has been reported from Alaska to El Salvador.

4. *Japan*

On the western side of the Pacific Ocean, the Japanese have recognised for over 50 years the existence of a dermatitis of unknown etiology which occurred among farmers inhabiting land near Lake Shinji, Shimane Prefecture. The dermatitis is called "koganbyo" or "lakeside disease" (Hunter, Ritchie, and Tanabe, 1951).

These authors reported that Tanabe in 1947 was able to produce experimental dermatitis using the furcocercous cercariae from a species of snail now known as *Polypylis hemisphaerula* Benson. This observation was confirmed and subsequently the definitive hosts were determined. They are the large starling (*Spodiopsar cineraceus* Tamminck), the sparrow (*Passer montanus saturatus* Stejnerger), and the wagtail (*Motacilla* (*Motacilla*) *grandis* Sharpe). The adult of this species of schistosome is designated as *Gigantobilharzia sturniae* Tanabe, 1948.

The snail intermediate hosts (with 3–10 per cent infections) were commonly found on submerged vegetation or mud of rice fields and irrigation canals. Dermatitis began in mid-May and reached a peak about mid-July to mid-August, and the degree and intensity of the infection appeared to be correlated with the aquatic activity of the rice farmers. Surveys made of other areas in Japan indicated that both the bird definitive hosts and the snail intermediate hosts were widespread. Aside from Lake Shinji, the cases of dermatitis in the farmers of Mie Prefecture as well as those of Aichi Prefecture were believed to be caused by the cercariae of *G. sturniae* (Oda, 1956*a*, 1956*b*). It is possible that there are other areas in Japan where koganbyo exists.

Yamaguti (1941) reported the presence of avian schistosomes in Japanese birds and described two new species: *Trichobilharzia corvi* (Yamaguti, 1941) McMullen and Beaver, 1945, from *Corvus corone corone* Linn., and *Ornithobilharzia emberizae* Yamaguti, 1941, from *Emberiza sulphurata* Temm. et Schleg. However, it is not known if these parasites are capable of producing cercarial dermatitis.

An interesting report was made by Ito (1956) on a brackish water furcocercous cercaria from a snail intermediate host, *Tympanotonus microptera* (Kiener) found in Chiba Prefecture (Tokyo Bay). The author named it *Cercaria tympanotoni* and suggested that on morphological grounds this cercaria might be dermatitis producing. Because of an insufficiency of snails infected with this parasite, no experimental data were obtained. However, this record indicates, for the first time in Japan, that perhaps in a brackish water environment there is a possibility of humans contracting cercarial dermatitis.

5. *China and Formosa*

There are no reported cases in man of avian cercarial dermatitis in China or Formosa. However, two species of bird schistosomes have been found in China; *Ornithobilharzia odhneri* Faust, 1924, from the Asiatic curlew, and *Ornithobilharzia hoepplii* Tang, 1951, from Swinhoe's snipe.

In Formosa, one species of avian schistosome, *Trichobilharzia yokogawai* (Oiso, 1927) McMullen and Beaver, 1945, has been isolated from the duck. The "nonhuman zoophilic" strain of *Schistosoma japonicum* in Formosa has been regarded as a dog strain, because there is a high incidence (62 per cent) of natural infections in dogs but no known occurrence in humans (Hsu *et al.*, 1954). In order to determine the effectiveness of this strain in causing cercarial dermatitis and other symptoms in man, Hsu and Hsu (1956) tested the infectivity of this strain of *S. japonicum* on five human volunteers. The cercariae of *S. japonicum* did cause the sensation of itching and the development of a rash or papule. There were systemic clinical signs, such as abdominal pain, headache, nausea,

anorexia, chest pain, and general malaise, which are normally absent from avian schistosome cercarial infection. Nevertheless, the Formosan strain of *S. japonicum* did not develop to maturity in the volunteers and consequently did not result in a typical schistosomiasis. There were no experiments on repeated infections in these volunteers to determine hypersensitivity reactions.

Japanese investigators had long suspected that *S. japonicum* ("human strain") might cause cercarial dermatitis. In 1909, Kobayashi studied the relations between "kabure," endemic dermatitis, and schistosomiasis japonica (Faust, 1924*b*). Recently Ishii and Ogawa (1952) reported that it was possible to produce dermatitis in rats with the cercariae of *S. japonicum* ("human strain") by repeated exposure to the cercariae. Characteristic lesions included macules, papules, erythema, edema, and vesicles. However, Hunter and his associates (1956), using mice, hamsters, and rabbits as experimental animals, were unable to repeat these results or similar findings reported by other workers and so concluded that the selection of the proper experimental hosts for studies on immunologic responses to schistosome infection is of critical importance.

6. *Malaya and the Philippines*

Buckley (1928) demonstrated that the dermatitis known as "sawah itch" in Malaya was caused by the cercariae of *Schistosoma spindale* Montgomery, 1906, obtained from *Planorbis pfeifferi*. Normally *S. spindale* causes serious schistosomiasis in mammals such as cattle, sheep, goats, horses, antelopes, and water buffaloes in India, South Africa, and Sumatra.

Another example of a mammal-infecting schistosome which causes dermatitis in man is *Schistosomatium douthitti* (Cort, 1914). This organism is found in the United States as a parasite in deer, mice, and muskrats.

A fruitful field for research would be a comparative study to determine the differences between the mammalian schistosomes, which can cause dermatitis in man (like *S. spindale*, *S. douthitti*), and the dog-infecting strain of schistosome (*S. japonicum*), which apparently does not cause natural cercarial dermatitis (koganbyo) among Formosan farmers.

Recently a bird schistosome belonging to the "*elvae*" group of cercariae was described by Sandosham (1953) as the cause of sawah itch in the Ayer-Lunging district, Negri Semilan, and the intermediate host was identified as *Lymnaea rosseana* Mabille. This dermatitis-producing cercaria was named *Cercaria Malaya I*, and an unsuccessful attempt was made to infect chickens with it.

Cercarial dermatitis in man in the Philippines has not been studied to any extent, probably because of the intense efforts on the part of the medical scientists to control the spread of schistosomiasis japonica. Tubangui (1947) listed *Austrobilharzia bayensis* Tubangui, 1933, as a schistosome from the mesenteric vein of a snipe, *Capella gallinago gallinago*. This finding is encouraging for those who are interested in further host examinations for the presence of avian schistosomiasis, especially in the sea and shore birds of the Philippines.

7. *New Zealand*

According to Macfarlane (1944, 1949*a*, 1949*b*) the reports of swimmer's itch derived from lakes Hawea, Te Anau, Alexandrina, and Rotoiti, and from several lakes in the Rotorua district, have not been confirmed. However, Macfarlane recovered schistosome cercariae from snails in lakes Wanaka, Hayes, and Wakatipu in the South Island. The etiological agent causing experimental dermatitis has been described and named *Cercaria longicauda* Macfarlane, 1944. The snail intermediate hosts are: *Myxas ampulla*, *M. arguta*, and *Limnaea alfredi*. The molluscan hosts in Lake Wanaka lived in beds of the pond weed *Myriophyllum robustum* and also on *Isoetes* spp., *Juncus* spp., and *Potamogeton polygonifolium*. In lakes Wakatipu and Hayes there were

fewer snails, associated with the weed *Ranunculus fluitans*. The definitive host, the teal *Fuligula novae zealandii*, rested on the weed beds through the summer and fed on the lake floor. The adult stage of *C. longicauda* has not been studied.

8. *Australia*

Fresh-water cercarial dermatitis has been known in Australia since Johnston (1941) first reported its presence in the Murray Valley swamps. He surmised that *Cercaria parocellata* Johnston and Simpson, 1939, from *Limnaea lessoni*, on morphological grounds, might be the parasite involved. Macfarlane (1952) made a further investigation and obtained reports of dermatitis at Albury, Birri, Loxton, Mannum, Murray Bridge, and Tailem Bend near Adelaide. According to this author, at all of these places the river spread into areas of shallow water, which allowed the molluscan hosts to build up a population in close association with water birds. He believed that most of the infection of humans occurred during periods of shallow water.

Swimmer's itch was also known to be present in Western Australia. Lake Bumbleyung in the Wagin region appeared to be the important area although other smaller lakes had also been the source of the infection. The third area in Australia suspected to have cercarial dermatitis was Narrabeen Lake, a small shallow coastal lake near Sidney. It has been reported since that these cases were caused by marine species of bird schistosomes, because this lake has an outlet to the Pacific Ocean and the water may not be fresh.

Macfarlane reported that the snail intermediate host *L. lessoni* occurred in both the Murray Swamp area and the Wagin region. Whether or not *Cercaria paracellata* was involved in both areas is not known. In the Murray River, *L. lessoni* lived in the often stagnant backwaters.

Johnston (1941) suspected that the black swan was the definitive host for *C. parocellata*, but confirmation has not been made. *Cercaria jaenschi* was reported by Macfarlane (1952) not to penetrate the skin of man even though it was a schistosome cercaria. Furthermore, the antigen prepared from these cercariae produced smaller and less persistent skin reactions than did the *C. parocellata* antigen.

B. MARINE CERCARIAL DERMATITIS

1. *California and Mexico*

Extended studies of marine snails as possible agents in the transmission of cercarial dermatitis were not made until several years after World War II. However, as early as 1942, Penner mentioned that the marine gastropods might be infected with dermatitis-producing schistosome cercariae. In 1950, he described as a new species *Cercaria littorinalinae* from the marine snail *Littorina planaxis* Philippi, which were collected along the rocky shores of the Coronado Islands in Mexico and from Bird Rock near La Jolla, California. The natural definitive host was the Wyman western gull (*Larus occidentalis wymani* Dicky and van Rossem). Penner (1953*c*) was able to infect experimentally with this species of cercaria the following birds: brant, cormorant, black-crowned night heron, western gull, budgerigar parakeet, Australian zebra finch, domestic pigeon, red jungle fowl, and linnet. The domestic duck did not appear to be susceptible to the infection. The adults of *C. littorinalinae* belong to the genus *Austrobilharzia* (Johnston, 1917) and have been given the name *Austrobilharzia littorinalinae* by Penner although the taxonomic description is still unavailable. This species of schistosome is therefore distinct from *A. variglandis* (Miller and Northup, 1926) Penner, 1953 (= *Microbilharzia variglandis* (Miller and Northup, 1926) Stunkard and Hinchliffe, 1951).

In the San Diego area, this marine species of bird schistosome has not been officially incriminated in cases of swimmer's itch although Penner (1950) did mention that he experienced the development of typical lesions after wading in sea water in this area

while collecting the snail intermediate hosts. Cercarial dermatitis can be produced experimentally with *C. littorinalinae*.

Recently Gradhaus and Keh (unpublished data, 1957) reported cases of swimmer's itch occurring on the beaches of the city of Alameda, bordering San Francisco Bay. *Nassarius obsoletus*, a marine snail intermediate host for *A. variglandis* on the Atlantic coast, was also the intermediate host in California. It was believed that the snails were introduced into this area together with the oysters that had been planted in the bay. The schistosome cercariae from these snails were identified as those of *A. variglandis*.

2. *Hawaiian Islands*

Chu (1952) first reported the presence of a dermatitis-producing schistosome cercaria from the marine snail *Littorina pintado* Wood in two bird refuges on small offshore islands near Oahu, known as Bird Island (Moku Manu) and Rabbit Island (Manana). The snails infected with schistosomes were found only in the sea benches where there were many small tidal pools constantly receiving a sea spray. Collectors of the snails from the sea benches of Rabbit Island experienced itching and, in some cases, developed typical schistosome papule lesions on their feet. It may be added that the distribution of infectious cercariae seems to be limited to the bird refuges, because Chu and Cutress (unpublished data, 1954) were unable to find schistosome-infected snails inhabiting any of the swimming beaches on the major islands of Oahu, Maui, Kauai, and Hawaii. The life history of this parasite has been reported by Chu and Cutress (1954). The natural definitive host for the adult stage was the ruddy turnstone (*Arenaria interpres interpres*), a shore bird which winters in the Hawaiian Islands. Chicks, ducks, and the sooty and noddy terns could be infected experimentally.

After a study of the morphological characters of the adult stage of the schistosome in the naturally infected turnstones as well as in the experimentally infected animals, the authors concluded that this species was the same as the species of schistosome reported by Stunkard and Hinchliffe (1951, 1952) from the eastern United States along the Atlantic Ocean, i. e., *Austrobilharzia variglandis*.

Penner (1953*b*) reported that the red-breasted merganser (*Mergus serrator* L.) was the natural definitive host for *A. variglandis* in the Atlantic coast. Munro (1944) states that this species of bird had been reported only as an occasional visitor to the Hawaiian Islands. However, Richardson and Fisher (1950) do not list the red-breasted merganser as a species found in the Hawaiian bird refuges. It can also be added that the western gull, a natural definitive host for *A. littorinalinae* in California, is not a species generally seen on Oahu.

The migration routes for shore birds in the Pacific Ocean have been studied by Baker (1951). On the basis of sight records, specimen collection, known statistics of breeding and wintering, and from a study of maps of the region, he established the following three flyways: (1) the Asiatic-Palauan, (2) the Japanese-Marianan, and (3) the Nearctic-Hawaiian. For each of the flyways the author listed the names of the regularly visiting and the uncommonly visiting shore birds. Of the 35 species mentioned, only the ruddy turnstone and the golden plover (*Pluvialis dominica fulva*) were the ones common to all of the three flyways. In the experience of the Hawaiian investigators, the golden plover was never found to be infected with the schistosome, in contrast to the ruddy turnstone.

King (1955) listed six major groups of sea birds found in the central Pacific Ocean. These are: (1) the albatrosses, (2) the shearwaters and petrels, (3) the terns, (4) the frigate birds, (5) the boobies, and (6) the tropic birds. Gulls and jaegers were listed as being occasionally seen. Chu and Cutress (unpublished data, 1954) did not encounter a single case of natural infection with schistosomes in limited examinations of sea bird pop-

ulations. The exact relation of the sea birds to the problem of transmission and reservoir hosts in Hawaii has yet to be determined.

The snail intermediate host, *L. pintado*, uncommon in Micronesia and apparently limited in its range to the northern Pacific islands, has been reported by Demond (1957) to exist in southern Japan, the Ryukyus, Bonins, northern Philippines, Marianas, Marshalls[4], Johnston Island, and Formosa. The experimental snail intermediate host used by Chu and Cutress, *Littorina scabra* L., has a much wider geographical range: from east Africa through the Indian and Pacific oceans to Hawaii and Tahiti, and from the Ryukyus, the Philippines, and Marianas, south to northern Australia. Since both the definitive and intermediate hosts for *A. variglandis* are widely spread in the Pacific area, one may surmise that marine schistosome infections of birds and snails may not be limited to the Hawaiian Islands and California and that with further investigation other areas might prove to be infected.

In determining the casual agent of swimmer's itch, or cercarial dermatitis, it is not sufficient to find schistosome-infected snails in the area because of the possible presence of other etiological agents which cause similar skin lesions. "Swimmers' Itch" (or "Pearl Harbor Itch") cases reported by Arnold and Bonnet (1950) are now suspected to have been cases of marine hydroid dermatitis, because the discovery of a medusa (*Sarsia* sp.) was made in the same location which Arnold and Bonnet reported to be a source of the dermatitis. This finding, together with the absence of schistosome-infected snails in the areas under study, suggests that these "Swimmers' Itch" cases of Arnold and Bonnet were not of cercarial origin (Chu and Cutress, unpublished data).

It is necessary, however, to point out that in the Atlantic coast, (such as Mill cove in Maine, Narragansett Bay in Rhode Island, and Long Island Sound, N. Y.) cercarial dermatitis was reported to be associated with clam digging (Orris and Combs, 1950; Sindermann and Gibbs, 1953). The intermediate host is a mud snail, *Nassarius obsoletus* (*Nassa obsoleta*), which is also an intermediate host for the marine schistosome in California. This species is not found in Hawaii as Edmondson (1946) listed *Nassa sertum* Bruguiere as the only local species. In several surveys made during 1951–54 by the Hawaiian investigators, the few bottom-dwelling gastropods from West Loch, Pearl Harbor, were never found to be infected with schistosome parasites.

Demond (1957) listed *Nassarius papillosus* (Linn.) as occurring in Hawaii. As yet, there is no report indicating that this or any other species of *Nassarius* is an intermediate host for schistosome in the central and south Pacific.

An example of the difficulty of determining the etiological agent for dermatitis caused by marine microorganisms is that reported by Strauss (1956) for the "Seabather's Eruption" in Guantanamo Bay, Cuba. This investigator was unable to find any snails infected with schistosomes. Serological tests of the patients showed negative evidence for the presence of cercarial dermatitis. A more fortunate experience than that reported by Strauss was given by Chu and Cutress (1955). Many construction workers contracted dermatitis when in contact with sea water in Hilo Bay, Hawaii. Although in this area, *Littorina pintado* and the ruddy turnstone were seen, no schistosome-infected snails were located. Instead, a marine hydroid, *Syncoryne mirabilis* (Agassiz, 1852), was found growing profusely on the surface of the submerged rocks near the site of construction. By chemical treatment, the hydroids were destroyed and the dermatitis was controlled.

Most of the conclusions incriminating marine schistosome cercariae in cases of derma-

[4] In 1955, at Eniwetok, C. E. Cutress found *L. pintado* and ruddy turnstones in the area, but among the specimens examined by him no schistosomes were found (personal communication, 1957).

titis have been based upon circumstantial evidence. The urgent need in diagnosing the cause of naturally occurring dermatitis is a technic (e. g., biopsy tests) which would yield direct evidence about the infective agent, so that proper control methods could be formulated.

3. *Australia*

Bearup (1955, 1956) showed that schistosome cercariae occurred in a marine snail, *Pyrazus australis* Quoy and Gaimard, in Narrabeen Lake, near Sydney, N. S. W. The cercaria was first identified as *Cercaria variglandis* later Miller and Northup, subspecies *pyrazi*, but was determined to be the cercaria of *Austrobilharzia terrigalensis* Johnston, 1917. The seagulls (*Larus novae-hollandiae*) from the Sydney district were heavily infected.

The incidence of schistosome infection in *P. australis* from Narrabeen Lagoon was 4–6 per cent, the higher level occurring during the hot months at the end of the year. Cercariae from these infected snails would infect young seagulls, budgerigars (*Melopsitacus undulatus*), and pigeons (*Columba livia*), but not domestic ducks or mice.

From Florida, U. S. A., several marine schistosome cercariae have been described (Hutton, 1952; Leigh, 1955; Penner, 1953*a*). These species are distinct from one another and different from *A. variglandis*. However, the extreme similarity in morphology of the three species, namely, (1) *A. variglandis* from the Atlantic, Pacific, and Hawaiian areas, (2) *A. littorinalinae* from southern California and Mexico, and (3) *A. terrigalensis* from Australia, raises the interesting question of whether or not they are actually one species with minor variations because of adaptation to the intermediate and definitive hosts in widely separated geographical areas.

DISCUSSION

Cercarial dermatitis is of worldwide distribution, and probably there are other areas where suspected cases of swimmer's itch occur but where no investigations have been made. In the Pacific Ocean area, many islands in the Polynesian, Micronesian, and Melanesian groups are worthy of exploratory studies for the presence of bird schistosomiasis. Likewise, other geographical areas such as China, Formosa, Indonesia, Viet Nam, the Philippines, and Thailand have yet to be investigated fully.

In the North American continent, swimmer's itch has been widely studied, yet data on schistosome infections in migratory birds are still limited. Most of the information on definitive hosts has been obtained through experimental infection. As a result, the question is frequently asked as to the degree of natural infection with schistosomes in other types of birds. In this connection, the problem of host susceptibility has been studied by many investigators. In our own experience, the marine schistosome adults found in the ruddy turnstone developed well in the sooty and noddy terns, but in chicks and ducks the adults did not remain viable for an extended period and the pathology was not entirely comparable to that in the natural host. This differential susceptibility between species and subspecies (or strains) of the birds is a challenging problem to workers who are interested in immunology. Such a study is important in relationship to speciation and distribution of both the fresh-water and marine schistosomes in birds.

Specificity of a trematode parasite for a host may be directly correlated with the host diet. An example of this correlation was reported by Oguri and Chu (1955) for the infection of domestic ducks by the cloacal trematode *Parochis acanthus* (Nicoll, 1906) Nicoll, 1907. The natural definitive hosts for this parasite are sea birds. When the infectious cysts of *P. acanthus* were given orally to mash-fed ducks, there were no infections in these experimental hosts. However, if the ducks were fed with squids from the sea, instead of the mash diet, it was possible to establish the

infection in them. This variation in host susceptibility caused by a change in diet suggests that seemingly contradictory results from host experimental infections for bird schistosomes may be due to differences in the diets fed the experimental hosts by the various investigators.

Substantial data, on the other hand, have accumulated during the past several decades regarding the bionomics of the intermediate hosts of the dermatitis-producing schistosomes. These data are chiefly concerned with (1) the habits of the snails, such as their food requirements, reproductive rates, adaptation to surroundings, and association with other plant and animal life, (2) the environmental conditions such as changes in pH and salinity in water, variation in temperature and amount of sunlight, and (3) susceptibility of the other species of snails in the locality to infection by the schistosome miracidia. This information is essential for understanding the reasons why the disease exists in specific localities. Many reports also indicate that an intimate association between the infected birds and the snail intermediate hosts is a necessity before cercarial dermatitis can be established as a "Disease of the Place."

For fresh-water snails, cultivation in the laboratory has not been a problem, but for marine snails, technics for their cultivation are yet to be developed. The bionomics of marine snails is a fascinating subject. Edmondson (1946) stated that: "A specimen of *Littorina pintado* remained attached to the plastered wall of the Marine Biological Laboratory, Honolulu, for nearly a year. When it was returned to sea water it regained its activity in a few minutes." Attempts are now being made to breed *Littorina* snails in our laboratory for use in experimental work on schistosomes.

The investigation of all phases concerned with marine cercarial dermatitis is indeed a green pasture for those who are interested in diseases associated with a marine environment. We encourage investigators in the Pacific area to participate in this field of study.

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